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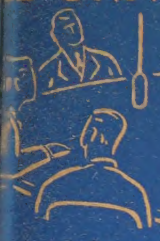

Round Table

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The Study of Growth and Its Meaning to Mankind

I. The Biological Aspects

An NBC Radio Discussion by T. C. BYERLY
C. P. RHOADS, J. ROBBINS
and PAUL A. WEISS

Including

IS MODERN SCIENCE GOOD OR EVIL?
By C. A. COULSON

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CONTENTS

Around the Round Table . . .

T. C. BYERLY, director of the Division of Animal Husbandry, United States Department of Agriculture, in charge of the research on animal production

C. P. RHOADS, M.D., director of Memorial Cancer Research Center, New York, since 1940; director of the Sloan-Kettering Foundation for Cancer Research since 1945; professor of pathology, Cornell Medical College; member of the Committee on Growth of the National Research Council; formerly associated with the Rockefeller Institute for Medical Research (1928–39)

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A Special Article from *The Listener*, the Magazine of the British Broadcasting Corporation

IS MODERN SCIENCE GOOD OR EVIL? *By* C. A. COULSON 12

THE UNIVERSITY OF CHICAGO ROUND TABLE

GEORGE E. PROBST, *Director*

CATHERINE D. JOHNSON, *Editor*

975th Broadcast in Cooperation with the National Broadcasting Company

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The Study of Growth and Its Meaning to Mankind

I. The Biological Aspects

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Mr. Weiss: We have assembled here to talk about a problem which we all believe is fundamental to the welfare of mankind now and to future generations. It is the problem of growth which we all recognize when we see it. We see children grow. We see mushrooms grow up fast in the woods. We see our gardens grow. We see bacterial cultures expand. And we see that there is growth that can do either harm or good. Our nutrition of food depends on it.

We want to discuss this today and to see how far science has proceeded in removing the mystery from the problem, even while leaving many of the unknowns still unknowns. While our ignorance is still vast, there is quite a bit which we now know.

Mr. Robbins, perhaps you would like to tell us why the study of plant growth is of particular significance to human welfare.

Mr. Robbins: When you spoke of the importance of growth to us, I could not help but think that the growth of plants is especially important because, as the result of their growth, we are furnished with all the food which animals eat. Whether it be other animals or plants themselves, all our food develops from the growth of plants. They and their processes of growth are, therefore, of very fundamental importance to us.

Mr. Weiss: Mr. Byerly, perhaps you can tell us about the raising of animals in regard to that and what its limitations are for human welfare.

Mr. Byerly: My particular task, of course, has to do with using the plants which are grown as efficiently as possible so that we may continue to have the meat which we want to eat. We have only so many acres of land to produce feed crops, and we have to produce a larger

amount of meat from those feed crops as our population grows. At th present time it looks as though by 1975 we might need the additiona product of a hundred million acres. We do not have that, so we hav to get higher yields of plants and higher yields of meat animals fron those plants which we do have.

MR. WEISS: While, of course, animal and plant growth is funda mental to our own nutrition, there are other forms of growth whicl are less beneficial. Perhaps we can turn to Dr. Rhoads to bring in her the medical end of this story.

DR. RHOADS: I am in a very bad spot here, because my colleagues ar all concerned with making more growth occur, and I am in the busi ness of restraining abnormal, erosive, corroding growth of the tissue of the body. I have to turn to you gentlemen for the fundamental prin ciples concerning the ability of cells—those entities which compose th body—to grow and to take advantage of these principles to restrain th kind of growth which we do not want—which means the cure o cancer.

MR. WEISS: Of course, we have some types of growth in man whicl are beneficial, like wound-healing, where growth is essential.

DR. RHOADS: We do, indeed; and we are constantly seeking mean for improving the ability of the tissues to grow in a normal fashion to compose the rounded, complete structure which we call a humar body. But the rough part of it comes when for reasons which are no quite clear some parts of the body attain the ability to grow in a wholly unrestrained, uncontrolled, and corrosive fashion, with even tual death. Actually, of course, this holds true in Robbins' and Byerly' experiments, although in a less difficult way.

MR. WEISS: Perhaps we should explain at this time why we bring together here today a botanist, a pathologist, a zoölogist, and an exper in animal nutrition and animal husbandry to talk about the same sub ject. Perhaps this is the time to bring our problem down from the leve of just conversation to a little more scientific plane. If I may take a few minutes, I will see whether I can formulate what the problem o growth really is—what it involves.

All living beings apparently start from some very minute microscopi —that is, not visible with the naked eye—parts of organic matter an develop into the visible products which we have among us, ourselve

included. That is why we are so interested in this process. We see the chick grow; we see man grow; we see the plants grow. How does this happen? We know quite a bit about it. We know that it starts with a defined physical-chemical system. It starts with an egg, let us say, in which a certain defined number of chemicals is included, and that is the "pantry" of this process, so to speak. It has to do with this initial equipment. That is its endowment; and from here on the process of development, which includes growth, goes on essentially like the development of an industrial plant.

We can compare directly the growth, the development, of a plant, let us say, in the botanist's sense with the development of an industrial plant. We start out with a blueprint, and the blueprint is so designed that the final product will have its purpose. It will produce textiles, or paints, or what not. This blue print, of course, is not directly capable of producing textiles or paints. It has to be put into effect, and it needs materials, human labor, and a certain rule of assembly by which these materials will be put together. This is a long process. It requires energy.

The same thing is true, of course, of the development of a plant in the botanical sense, of an animal, and of man. We have in the egg the blueprint—a physical-chemical equipment, the raw materials, and a rule of assembly, so to speak, which, if it is given a chance to develop, will be put into effect and gradually develop into man, or frog, or plant.

When I say that it has to be given all the necessary facilities for this, it is the same as in a plant, again building up an industry. We have to have the building materials, and we have to have steel and whatever it takes. If there is a critical shortage in any one of those, then, of course, the building process will be stopped. The same thing is true in the case of the building-up of an individual. The process requires a certain number of elementary ingredients.

Mr. Robbins: While you speak of the blueprint, of course you do not mean that in the eggs there is a minute man, or a minute frog, or a minute toad, do you?

Mr. Weiss: No. I am glad that you brought this up. We are viewing this blueprint as a state of organization, of physical-chemical realities, of things which are tangible, which are there at the time.

Dr. Rhoads: But there really is a framework, a pattern in the fertile egg, which permits the development, under normal circumstances, of a fully formed chick.

MR. WEISS: That is right, but only provided all the interactions, th whole course, which starts out with the egg, is provided for it. Othe wise, the course of development will be thrown off into abnormal r sults.

DR. RHOADS: Mistakes in manufacture can occur.

MR. WEISS: That is right.

MR. BYERLY: Mistakes in the amount of stuff which is put into th egg or supplied to the embryo can occur too. Something more than si hundred million chicken eggs are put into incubators every year whic do not hatch at all. This would feed a lot of people with all the egg that they want; they are perfectly wasted.

DR. RHOADS: Why does this occur?

MR. WEISS: It can be even due to a deficiency in the initial equip ment. If we lack something in the "pantry," if our sugar is lacking for example, the cake, of course, will not be sweet. If something essen tial is lacking in the initial equipment of the chick egg, the chick wil either not come out at all or will be a bad kind of chicken with al kinds of malformations.

But it may also be that in the course of development some of th essentials will not have been fed in, in the accessories which have t come in all the time. Perhaps this is a time to talk about some of thes accessories which we know which have to come in after the egg i started on its way, such as growth factors in animals or plants.

MR. BYERLY: The egg is particularly sensitive to some things an apparently insensitive to others. For example, the kinds of protein and the amounts of proteins in an egg are relatively insensitive, bu the kinds of vitamins which are there are very sensitive to the kinds o vitamins and the amounts which are present in the diet of the hen. I is very necessary that her diet contain vitamin D and vitamin A an riboflavin and vitamin B_{12}. As a matter of fact, this last one, thoug it is present in very minute amounts—I believe that 1 microgram i sufficient to see a chick embryo through not only to hatching but fo two or three weeks after—is all that is required. Yet it is a very im portant thing from the standpoint of utilizing our feed supplies.

As we moved up with soya-bean meal, a vegetable protein sourc as the main source of protein for our hens, we have had to suppl from animal protein factors or from fermentation residues this minut

mount of vitamin B_{12} in order to utilize these vegetable protein con-ntrates. This is the thing which we will have to come to many times n supplementing the poor grade of stuff we give our animals to eat.

MR. ROBBINS: Yes. I might point out something which is recognized y all of you. The basic source of these supplementary food substances, he vitamins, is in plants. They are made by plants—not by all plants, ut the basic source of them is in plants. There is another factor, too, vhich is of great importance, and that is the trace mineral elements. That has proved, as you know, Byerly, from your own experiments, of reat importance in the raising of livestock in some areas.

MR. BYERLY: Your vitamin B_{12}, of course, contains cobalt, does it ot? That is one of these minerals.

MR. ROBBINS: Right; right!

DR. RHOADS: You infer here that the principal factor is the lack of ssential elements. Is it not possible that an excess may exert some in-urious effect and may create abnormalities in the embryo? For exam-ple, if I add lead to the developing chick embryo, no brain will form.

MR. BYERLY: Quite!

MR. WEISS: This certainly is true of vitamin A; extra vitamin A can ransform the surface of skin into a mucus-secreting surface and give quite abnormal results.

MR. ROBBINS: Of course, there is not only this matter of things which re needed for growth but there are also, without any question, dem-onstrations of substances which inhibit growth and which are not nec-ssarily an excess of an essential substance.

MR. WEISS: This brings us really to a very crucial point. The fact is fter all that, when we look at growth, it does not go on forever. There re certain limitations. We do not grow up above a certain size, and we do not know when we reach our limit; but we are more or less onvinced that for most animals there is a limit.

MR. ROBBINS: I think that I have reached my limit.

MR. WEISS: We all have, with one qualification. When I spoke of n industrial plant and the building of a plant, we were essentially hinking of a construction process where things are being assembled nd put together. In organic matter the story is somewhat different.

Along with the construction there is always going on destruction of substance—breakdown. That starts on the molecular level. The organic compounds are constantly made and broken, as we now know, particularly as shown from the studies of the radioactive tracers, which have been so extremely valuable in elucidating the molecular basis of growth. The same thing happens, of course, in our tissues. I do not believe that all people know that their skin, for instance, is growing constantly—new cells are being produced on one side of the skin, and then they move up to the surface, form a horny layer, and are being shed gradually. Our hair, of course, and the nails are very visible expressions of that process. The same thing is happening in the blood. There is constant reproduction of new blood cells; and in the intestine and in glands we have the same process.

So, really, when we do not see any active increase in a system, that does not mean that its growth has stopped. It means only that production and destruction have come to an equilibrium, just like a bank account in which we take out about as much as we put in, so that we do not see much movement in the total balance.

MR. ROBBINS: There is really no net gain necessarily as a result of these growth processes which you have been describing?

MR. WEISS: That is right. In the development the characteristic thing is that in the early phases the production leaves a surplus over the destruction, but the downgrading, so to speak, increases, so that the total increment reaches a ceiling and there will be finally the end. I suppose that the question of unrestrained growth simply suddenly removes that ceiling for certain parts of the body. Is that not true, Dr. Rhoads?

DR. RHOADS: We presume that to be the case. Certainly it appears that, from time to time in the process of reproduction, cells are born which have greater competence than their parents and their brothers and sisters. Thereby they may actually rob their parents and brothers and sisters of nutritive materials. Or it is believed perhaps in some instances that they may actually stop or interfere with the growth property of their other brothers and sisters. We see exactly this occurring in the growth of bacteria. We suspect that it occurs in plants and with the cells with which our bodies are composed.

The answer to this, we believe, may be coming if research can continue. We wish to define the peculiar appetites of the normal cells and these abnormally growing cells of the body, because if we can define

a particular greed of a particular kind of cell, we can poison or make explosive by incorporating radioactive atoms its preferred diet and thereby destroy the cell.

MR. ROBBINS: How do these abnormal cells get that way? Are they simply wide variants from the normal, or do they acquire new properties somewhere along the way?

DR. RHOADS: It seems perfectly clear that they acquire new properties. These properties are not so well defined as we would like. Many of them, we believe, exist because of indirect evidence. With more adequate studies, such as with an electron microscope, it is apparent from limited studies that there are in these new cells actually new, small components which can be seen and may represent little chemical factories which give these cells their unusual properties.

MR. BYERLY: Do you suppose that we can make these cells change back to the normal pattern; or is the change irreversible?

DR. RHOADS: I do not know. It is already clear that up to a certain point in the development of these abnormal properties the cell will revert under certain particular circumstances. We suspect that beyond that point it is in part irreversible, but we can kill it or restrain its growth even though it may not revert to normal.

MR. ROBBINS: Of course, these abnormal types of growth also occur in plants. There are plant tumors, and there are abnormal types of growth in the fungi. I am sure that if research on these abnormal types of growth in plants can be pushed, that there may be some information of value to your special problem, Dr. Rhoads.

DR. RHOADS: I just could not agree more. I have been trying to get you to work on fungi for years and to give us the answer to the most important phenomena which you have observed there.

MR. WEISS: This brings up a problem which we have not really discussed at all. When we were talking about growth, we were focusing only upon one component of the total process of development—namely, the increase of organic mass—that is, of a given type of cell or a given type of body. But, along with this change, we also have an increase in diversity, differentiation—that is, the appearance of more different types of molecules, of new types of cells—liver cells, kidney cells, skin cells. They do not exist really in the egg as such, so they appear on the way. What we are talking about now is actually a deviation of this proc-

ess of differentiation. Something has gone wrong along that line, and we should not overlook the fact that there is more in common, than different, between the abnormal cell and its mother tissue from which it comes. It still is a part, a "chip off the old block," so to speak; and it still would not grow perhaps by transferring it from man into rat or into mouse or chicken. It would still remain a human type of cell—as a matter of fact, may even remain the same type of tissue, only with a slightly different history. Is that not correct?

DR. RHOADS: Yes. That is a very interesting and important phenomenon. We are beginning to learn now that we can transplant tissue from one species to another under very special and very transient circumstances. This tissue, when transplanted, retains apparently much of its original function. Why it does not persist is very poorly understood, and this resistance to transplantation may be one of these important factors of the control of cellular populations which we all wish to know more about.

MR. WEISS: You know my interest in that, but our ignorance is really immense.

MR. BYERLY: There is a normal competition too among the body parts which is quite a protection, I think. For example, if we supply a calf for six months with adequate proteins, vitamins, and minerals, but only enough calories to keep him at constant weight for six months' time, we do him no harm at all, in spite of the fact that he would normally have doubled his weight in that period of time. When he is refed a sufficient amount of calories, he grows very fast. I believe that the same thing or a comparable thing is true with man.

MR. WEISS: Would you think that that calf ages as rapidly as it would normally, if it were fed the calories?

MR. BYERLY: This, of course, is speculative, but there are experiments to show that rats held on a subnormal plane of nutrition will outlive rats held on a full plane of nutrition. I expect that it makes quite a difference as to what kind of starvation it is, though.

MR. WEISS: So actually the problems of growth and size reach right into the problems of life-span probably too.

MR. BYERLY: I think that that is very true.

DR. RHOADS: Of course, means are beginning to come to hand by

which these growth-controlling influences are being better understood. Studies at the University of California have really created rats as big as cats by injecting the little animals with extracts of the pituitary gland at the base of the brain. There are limits to this, but it certainly does exert a profound influence.

MR. WEISS: You would agree that, while we are convinced from our studies of growth that there is a ceiling, we have not necessarily reached that ceiling in production of plants or in production of animals and that we can strive by further research to improve the growth situation.

MR. ROBBINS: I think that we have not reached the ceiling, but I would point out that the production of food has a potentially finite end to it, while the production of living things is infinite in its potentialities.

MR. WEISS: You mean that we will reach the ceiling some day . . .

MR. ROBBINS: Yes, some day.

MR. WEISS: . . . and that, after all, we might just as well be aware of it and adjust ourselves to that process of approximation?

MR. BYERLY: Within limits, until we have reached that ceiling, though it is very important for us to use every means available to increase the growth rate of young animals and also, I suspect, of young plants, because they are most efficient at that time. Twenty years ago it took at least four pounds of feed to make a pound of chicken. Nowadays we do it on three, simply because we grow our chickens faster. We have not changed the adult size of things at all.

MR. WEISS: How do we come by those improvements?

MR. BYERLY: Partly through selective breeding—growth rate is itself an inheritable thing—and partly, and very largely, through improvement in nutrition of our animals.

MR. ROBBINS: How much can we modify an animal by its nutrition? We cannot, for example, change a mouse into an elephant by feeding it peanuts, can we?

MR. BYERLY: No. But we can get it to grow faster to whatever capacity it has. The capacity is pretty well fixed genetically, but we can get it up to that ceiling in a whole lot shorter time by nutrition.

DR. RHOADS: Robbins, how is it that you botanists can make giant plants—like the giant chrysanthemums which I strive so hard to raise?

MR. ROBBINS: That is partly by modifying the pattern in the plant —the blueprint of which Weiss spoke earlier—by polyploidy—and by crossing we get a different pattern in the cells from which this chrysanthemum starts. The means by which those patterns are changed are complicated, and I think that I will not attempt to elaborate on them here.

MR. WEISS: It has become plain by now in our discussion, I think, that this is the type of research which is really of most fundamental significance to human welfare and that it cannot be done in the individual channels of specialization—of particular operations such as in a botany department, or zoölogy department, or in nutrition, or in cancer alone. What we have been talking about here is essentially bringing together these various viewpoints. It shows that we speak a common language and focus on the same problems. The bacteriologist, the botanist, the nutritionist, the biochemist . . .

MR. ROBBINS: Right!

MR. WEISS: . . . the geneticist—they all have to work together jointly in order to link these problems and to bring real advance and progress in that field. We have to come out from our isolation. We must not be isolationists in our science, and I am happy to say that training and facilities for that are being created right now.

MR. ROBBINS: I think growth illustrates more perhaps than any other process the unity of science. The fact is that studies on the growth of very simple organisms may contribute to our knowledge of the growth of higher animals and higher plants and abnormal growth in those more complex creatures.

MR. WEISS: You will agree that we cannot understand really abnormal growth, except against the background of knowing what normal growth implies.

DR. RHOADS: Precisely! And this creates the unhappy position of the investigating doctor who is constantly dependent upon the fundamental scientist and all these related fields.

MR. BYERLY: We certainly must have more research in this field if we are to continue to eat the kind of diet which we want.

MR. ROBBINS: And should have.

MR. WEISS: So it is really research, do you not think, which should

be emphasized along those lines? Are there any particular lines of research which should be singled out for special attention and favored treatment? Or should we follow Robbins' suggestion that the unity of science really would not permit such a breaking-up of task forces?

MR. BYERLY: I think that research is done by individuals; support should go to those individuals capable of doing research, either by demonstration or potentially capable of doing it in this field.

DR. RHOADS: And they must have continuity of research opportunity, not year to year.

MR. ROBBINS: That is very important.

MR. WEISS: Do you think that we now do invest enough in those potential brains—investigators—and stimulate their curiosity and their daring and adventure?

MR. ROBBINS: We are deficient in finding them, in training them, and in supporting them.

MR. WEISS: This discussion has at least pointed a way to the future. We are all convinced that the problems of growth and development are of very fundamental significance and also of interest to us as they are to man in general.

We have made remarkable progress in the last decades, not in finding the answers but at least in elaborating ways how to get to the answers. We have shown that research, unrestrained, well-supported, imaginative research, will have to be continued on a much larger scale if one day we want to have the answers to these very fundamental problems.

A Special Article from *The Listener*, the Magazine of the British Broadcasting Corporation

IS MODERN SCIENCE GOOD OR EVIL?*

By C. A. COULSON

Professor of Theoretical Physics, King's College, London University

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"With the monstrous weapons man already has, humanity is in danger of being trapped in this world by its moral adolescents. Our knowledge of science has clearly outstripped our capacity to control it. We have too many men of science; too few men of God. We have grasped the mystery of the atom and rejected the Sermon on the Mount. Man is stumbling blindly through a spiritual darkness while toying with the precarious secrets of life and death. The world has achieved brilliance without wisdom, power without conscience. Ours is a world of nuclear giants and ethical infants. We know more about war than we know about peace, more about killing than we know about living. This is our twentieth century's claim to distinction and to progress."

THOSE words of General Omar Bradley's are certainly striking, and I think I can see two distinct trains of thought behind them. In the first place he is imagining a kind of balance-sheet, in which the good effects and the evil effects of science are weighed, the one against the other. In the second place he is echoing a fear that is becoming more and more outspoken today; are we the kind of people who can be trusted to use the astonishing discoveries of these last hundred years in a right way? Anyhow, what kind of people are needed for this? Can we match the indubitable progress of science with a corresponding progress in conduct or in wisdom?

If I understand General Bradley correctly, I believe he would say that at present the evil effects of science outweigh the good: and that

* See *The Listener*, February 21, 1952. From a talk presented on the Far Eastern Service of the BBC.

the events of recent years have shown no compensating moral and ethical progress. We are like people in a runaway train whose brakes have not been made adequate for the gradients on the line, and which must therefore go hurtling madly to destruction. General Bradley is not alone in thinking like this. I suppose most of us would agree that H. G. Wells was one of our foremost interpreters of science in its effect on human life: the last book which he wrote shortly before his death was called *Mind at the End of Its Tether*. That in itself is pretty suggestive of this fear. But here are some of his words from inside the book: "The end of everything we call life is close at hand, and cannot be evaded." It is as if science, and scientific discovery, the work of our hands and of our minds, has somehow grown evil as it developed. We are under judgment: the darkness around us, which is moral and spiritual darkness, is closing down over the mental and intellectual light that we have striven to attain, and will finally put it out.

Thomas Hardy ended *Tess of the D'Urbervilles* with these words: "Justice was done: the President of the Immortals had finished his sport with Tess." If we want to say that human life on this earth is a kind of experiment, then our twentieth century's claim to distinction is that it has shown the experiment to be a failure. From that day when man first ate the forbidden fruit of the Tree of Knowledge, he was doomed—it is our peculiar privilege that our mastery of the atom and our probing into the precarious secrets of life and death have provided an eminence from which that doom can be seen: for the outline of the future has a face of violence. The fire which we have kindled has not merely scorched our fingers: it has become our funeral pyre. The astronomers tell us that this earth may have come into existence as part of the relics of a great supernova explosion of some star, an explosion which left the planets as its legacy. Humanity is behaving in such a way as will ensure that the earth ends as it began, with another great bang. But this time it will be a human bang, as the explosion of some super-atomic bomb finally reveals both man's scientific brilliance and his moral adolescence.

I hope I have not put that too strongly. I did want to bring out the two chief points: first, that the evil uses of science exceed the good, and second that spiritual progress has not kept pace with scientific progress. I know that General Bradley is a distinguished man: but I do wonder whether he has got things entirely right this time. I must say that the more I think about it, the less sure I am that I agree with

him. Is it really true that the fruits of science have been sour and not sweet? Take medicine, for example. I know that many governments throughout the world are even now perfecting the technique of bacterial warfare, so that harmful disease germs may be spread over whole communities in the event of war. That sounds dreadful enough. But equally well I know that in England, a little over one hundred years ago, the average age of death was about twenty, and now it is more than double. Bacterial warfare, even if it took place, would hardly be able to destroy as much life as medical science has saved, in this and other ways.

A few years ago I lived in a little cottage in the country; it was so remote that only two buses each week came to take people to the nearest town. The cottage was old, and very attractive. The ceilings rested on beautiful oak beams which stretched from one side of the cottage to the other. There was only one disappointing feature: I could not stand up in the ground-floor rooms. To be precise, I could stand up between the beams but when I moved sideways I was liable to bump my head hard against them. I admit that I am slightly above average height, but it did seem to me ridiculous that a ceiling should have been built so low as that. A little while later I found the explanation. This cottage was about three hundred years old: and in those days people were between six inches and a foot shorter, on the average, than they are now. The height of those rooms would have been quite reasonable then. And the reason for our better physique now? Scientific knowledge of proper food to eat, and proper sanitation.

We have learnt how to control diseases. It is not long since smallpox used to kill every year one person in each thousand of the population of Britain. Now it is an extreme rarity for a single death to occur from this cause. When I was thinking what I should say in this broadcast, one of my children was lying in bed, ill. But he was being cured, as thousands of people are now being cured every day, by doses of penicillin. General Bradley should have remembered that it was actually during a war, when supplies of quinine were cut off from the British and Americans, that scientists found a synthetic substitute (more precisely, several substitutes) so that malaria could be kept in check. I believe that if we really wanted, we could now wipe malaria off the whole face of the earth, just as smallpox has been wiped out of Britain.

One of the keynotes in all this is power. There is no doubt that modern science has put into man's hands almost limitless power. What

I am not so clear about is that this power has, on balance, been used badly. When I think of the wonderful way in which we can build great dams, or change the paths of large rivers, and of how, when this is done, as in the Tennessee Valley of America, rich full life can be brought back to derelict areas; when I imagine the great Bhakra and Nangal dams now under construction in the Punjab which will open up to agriculture no less than 1,500,000 acres of land, at present growing nothing; when I think of the hundred or more distinct radio isotopes that are now being provided by the atomic piles in Britain and America, making possible a much deeper knowledge of the way in which our bodies work and of the manner in which they may be healed, then I refuse to believe that science is one of the devil's trump cards. It is a gift from God, and, on balance, the gift has been well used.

This brings me to the second—and more interesting—of General Bradley's points. He claims that we can detect no progress in ethical conduct that could match the progress in science. But why should we? Why should we suppose that ethics change in the same manner that our science changes, by newer and newer discoveries? I see no reason at all for supposing that ethical principles should progress in the same way as science progresses. The great religious leaders of the past have laid down principles of behaviour which stand for all time. When Lao-tze in China, or the Old Testament prophets in Israel, or any of the other spiritual giants of former days, spoke of the nature of man and his relationship to his fellow men, they were saying something which, if it changed at all, would change far more slowly than our knowledge of the physical and biological universe. That is one reason why the great ethical principles are so simple: "Love thy neighbour as thyself"; "covet not thy neighbour's house"; "do justly and love mercy." You cannot progress from these. Whistler once said: "Art, since it begins with the infinite, cannot progress further." The same is true of ethical principles of conduct. Whereas no one can read a scientific text book that is more than fifty years old without feeling that much of it is unrealistic, yet, whether we are Christian, Mohammedan, or Buddhist, we can study our sacred scriptures with profit and with a sense that they do apply to the conditions of this twentieth century.

This does not mean that there should be no changes in human conduct. For the principles in which we believe, and on which we base

our behaviour, must be expressed in terms appropriate to each new generation. The principle does not change, but the application does. In the early years of this century a book was published which discussed the moral limitations which were imposed by general consent on the conduct of war. It concluded that a soldier must refuse to cut down a single fruit-tree or discharge his firearm from a balloon, even if commanded to do so by his superior officer. Yet today, as we all know, the total destruction of cities, the scorched-earth policy, massed bombing from the air—all these are common and largely accepted. Are we morally worse now than we were at the beginning of the century? Not necessarily. It is only that our problem, the problem of peace and war, has been lifted on to a new plane of decision by the nature of modern weapons of war. Deep within us, we know what are the principles of right conduct, just as they knew them in the year 1900; and they are the same principles. You could not say this of science, for not even the principles of atomic fission were then known; today they are a commonplace.

The future of our civilisation lies not in a neglect or refusal of science, coupled with a more intensive study of the Sermon on the Mount, or any other sacred scripture. It consists in bringing the two together, so that science is used to express the ethical principles in ways appropriate to today. Just before the last war began, Lord Samuel said: "The world needs above everything else a synthesis of philosophy, science and religion; and until philosophy, science and religion reconcile themselves, mankind is not likely to escape from the perils that surround it." That is as much true today as it was in 1938. Power without purpose, knowledge without responsibility, science without conscience: these never have been, and never will be, a fulfilment for mankind.

This is why I do not go all the way with General Bradley, who seems to me to want to deny science. Nor, of course, can I agree with those people who say that science is all that we want. Plenty of people do say this. In a recent book written by a distinguished British scientist, the author speaks of the chaos and uncertainty and fear of our generation, and of what he calls the chasm that he has seen open in the mind of man during the space of a single life-time. Then he concludes: "Can science save us? Let us stop pretending. If science cannot, nothing can." If you finish there, and do not add religion and philosophy, then what he has said seems to me entirely false.

But philosophy alone is not enough, either. Bertrand Russell, in his

latest book, says that "man now needs for his salvation only one thing —to open his heart to joy and to leave fear." It may be right to say this. But we know it needs more than philosophy to be able to do it. The good life is not purely philosophical, nor purely scientific, nor purely religious. It is compounded of all three elements. I admit that our twentieth century has emphasized heavily the scientific aspect; but I believe it was necessary that this should be done. If we manage to survive total destruction in the rest of this century, those scientific discoveries, such as the mystery of the atom and the precarious secrets of life and death which have distressed General Bradley, will be seen not as the forerunners of our doom, but as stepping-stones, leading us to a fuller and a finer life.

DEC 1 1952

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606 MANKIND IN A REVOLUTIONARY AGE—*Prime Minister Jawaharlal Nehru, Robert Redfield*

617 MORALS AND HIGHER EDUCATION—*John J. Cavanaugh, Robert M. Hutchins, F. Champion Ward*

629 "NO CROSS, NO CROWN"—*Bernard M. Loomer, Milton Mayer, Carl Friedrich von Weizsäcker*

630 ONE PHILOSOPHY FOR ONE WORLD—*Reuel N. Denney, Richard P. McKeon, Alan Watts, L. L. Whyte*

650 HUMAN RIGHTS—*Ales Bebler, Richard P. McKeon, Emelio Oribe*

651 HOW CAN HUMAN RIGHTS BE ENFORCED THROUGHOUT THE WORLD?—*Herman Finer, Richard P. McKeon, Alan Simpson*

656 CONFUCIUS AND PRESENT-DAY CHINA—*Herrlee G. Creel, Earl H. Pritchard*

659 POETRY BY T. S. ELIOT—*T. S. Eliot*

666 IS THERE A BLACKOUT OF HISTORY?—*William Henry Chamberlin, Louis Gottschalk, Milton Mayer*

671 NATIONAL SECURITY AND INDIVIDUAL FREEDOM—*Francis Biddle, Robert Carr, Alan Simpson, Adlai Stevenson, Harold C. Urey*

673 WHAT DO AMERICANS BELIEVE ABOUT THEIR FELLOW-MEN?—*William R. Ming, Jr., Malcolm P. Sharp, Louis Wirth*

690 WHAT ABOUT RETIREMENT?—*H. L. Bills, Elizabeth Breckinridge, Robert J. Havighurst, Virgil Martin*

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